

What is claimed is:

- 1 1. A method for efficient convolution, comprising the steps of:
  - 2 preparing a plurality of segmented perceptual response frequency spectra by
  - 3 removing high frequency components from a plurality of segmented response
  - 4 frequency spectra;
  - 5 generating a plurality of segmented input frequency spectra from a plurality of
  - 6 segmented input signals; and
  - 7 performing a frequency domain convolution method to generate convoluted signals
  - 8 using said plurality of segmented perceptual response frequency spectra and said
  - 9 plurality of segmented input frequency spectra;
  - 10 wherein said plurality of segmented perceptual response frequency spectra are
  - 11 generated by removing high frequency components from said plurality of segmented
  - 12 response frequency spectra based on a threshold.
- 1 2. The method for efficient convolution as claimed in claim 1, wherein said efficient
- 2 convolution is used for generating artificial room reverberation and said threshold is
- 3 based on a threshold in quiet, said threshold being determined by the minimum
- 4 amount of energy in a pure tone detected by a human hearing system in a noiseless
- 5 environment.
- 1 3. The method for efficient convolution as claimed in claim 1, wherein said frequency
- 2 domain convolution method is an overlap-and-add method by using FFT.
- 1 4. The method for generating efficient convolution as claimed in claim 1, wherein said
- 2 frequency domain convolution method is an overlap-and-save method by using FFT.

1 5. The method for efficient convolution as claimed in claim 1, wherein said segmented  
 2 input signals have a segment size for segmentation and in the step of performing a  
 3 frequency domain convolution method to generate convoluted signals, first and  
 4 second segments of convoluted signals are generated by convolution using a block  
 5 size smaller than the segment size.

1 6. A method for efficient convolution, comprising the steps of:

2 preparing an impulse response  $h[n]$ ;

3 segmenting said impulse response into  $M$  segmented impulse responses  $h_s[n]$ ,

4 wherein  $h_s[n] = \begin{cases} h[n + sN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, s = 0, 1, 2, \dots, M-1;$

5 transforming said  $M$  segmented impulse responses  $h_s[n]$  by DFT to form  $M$

6 segmented frequency spectra  $H_s[k]$  with  $0 \leq k < 2N$ ;

7 removing high frequency components from said  $M$  segmented frequency spectra  $H_s[k]$

8 based on a threshold to form  $M$  sets of segmented perceptual response frequency

9 spectra  $H'_s[k]$ ;

10 receiving and segmenting an input signal  $x[n]$  into a plurality of segmented input

11 signals  $x_r[n]$ , wherein  $x_r[n] = \begin{cases} x[n + rN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, r = 0, 1, 2, \dots, \infty;$

12 transforming each segmented input signal  $x_r[n]$  by DFT to form a segmented input

13 frequency spectrum  $X_r[k]$ ;

14 multiplying said segmented input frequency spectrum  $X_r[k]$  with said  $M$  sets of

15 segmented perceptual response frequency spectra  $H'_s[k]$  for  $s = 0, 1, 2, \dots, M-1$  to

16 form  $M$  segmented output frequency spectra  $Y_{r,s}[k] = X_r[k] \cdot H'_s[k]$ ;

17 inverse transforming said  $M$  output frequency spectra  $Y_{r,s}[k]$  to form  $M$  segmented  
 18 output signals  $y_{r,s}[n]$ ; and  
 19 performing overlap-and-add summation of said  $M$  segmented output signals  $y_{r,s}[n]$  to  
 20 form a final output signal  $y[n]$  according to

$$21 \quad y[n] = \sum_{r=0}^{\infty} \sum_{s=0}^{M-1} y_{r,s}[n - rN - sN].$$

1 7. The method for efficient convolution according to claim 6, wherein said impulse  
 2 response has a length  $L$  and  $M = \left\lceil \frac{L}{N} \right\rceil$  is a smallest integer larger than  $L$  divided by  
 3  $N$ .

1 8. A method for efficient convolution, comprising the steps of:

2 preparing an impulse response  $h[n]$ ;

3 segmenting said impulse response into  $M$  segmented impulse responses  $h_s[n]$ ,

4 wherein  $h_s[n] = \begin{cases} h[n + sN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, s = 0, 1, 2, \dots, M-1;$

5 transforming said  $M$  segmented impulse responses  $h_s[n]$  by DFT to form  $M$   
 6 segmented frequency spectra  $H_s[k]$  with  $0 \leq k < 2N$ ;

7 removing high frequency components from said  $M$  segmented frequency spectra  $H_s[k]$   
 8 based on a threshold to form  $M$  sets of segmented perceptual response frequency  
 9 spectra  $H'_s[k]$ ;

10 receiving and segmenting an input signal  $x[n]$  into a plurality of segmented input

11 signals  $x_r[n]$ , wherein  $x_r[n] = \begin{cases} x[n + rN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, r = 0, 1, 2, \dots, \infty;$

12 transforming each segmented input signal  $x_r[n]$  by FFT to form a segmented input

frequency spectrum  $X_r[k]$ ;  
buffering said segmented input frequency spectrum to form buffered segmented input  
frequency spectra  $X_{p-s}[k]$  for  $s = 0, 1, 2, \dots, M$  and  $p = 0, 1, 2, \dots, \infty$ ;  
multiplying said  $M$  sets of segmented perceptual response frequency spectra  $H'_s[k]$   
with last buffered  $M$  segmented input frequency spectra  $X_{p-s}[k]$  to form products  $X_{p-s}[k] \cdot H'_s[k]$  for  $s = 0, 1, 2, \dots, M-1$  and adding said products together to form a  
segmented output frequency spectrum

$$Y_p[k] = \sum_{s=0}^{M-1} X_{p-s}[k] H'_s[k], \text{ for } 0 \leq k < 2N-1;$$

inverse transforming said segmented output frequency spectrum  $Y_p[k]$  to form  
segmented output signals  $y_p[n]$ ; and  
performing overlap-and-add summation of said  $M$  segmented output signals  $y_p[n]$  to  
form a final output signal  $y[n]$  according to

$$y[n] = \sum_{p=s}^{\infty} y_p[n].$$

9. The method for efficient convolution according to claim 8, wherein said impulse  
response has a length  $L$  and  $M = \left\lceil \frac{L}{N} \right\rceil$  is a smallest integer larger than  $L$  divided by  
 $N$ .

10. A method for efficient convolution, comprising the steps of:

preparing an impulse response  $h[n]$  of ;  
segmenting said impulse response into  $M$  segmented impulse responses  $h_s[n]$ ,

wherein  $h_s[n] = \begin{cases} h[n + sN], & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases}, s = 0, 1, 2, \dots, M-1;$

5 transforming said segmented impulse responses  $h_s[n]$  by DFT to form  $M$  segmented  
 6 frequency spectra  $H_s[k]$  with  $0 \leq k < 2N$ ;  
 7 removing high frequency components from said segmented frequency spectra  $H_s[k]$   
 8 based on a threshold to form  $M$  sets of segmented perceptual response frequency  
 9 spectra  $H'_s[k]$ ;  
 10 receiving and segmenting an input signal  $x[n]$  into a plurality of segmented input  
 11 signals  $x_r[n]$ , wherein  $x_r[n] = \begin{cases} x[n + rN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, r = 0, 1, 2, \dots, \infty$ ;  
 12 overlapping and adding adjacent segmented input signals to form a plurality of  
 13 overlapped-and-segmented input signals  $x'_p[n] = x_{p-1}[n + N] + x_p[n]$ , wherein –  
 14  $N \leq n \leq N - 1$  and  $p = 0, 1, 2, \dots, \infty$ ;  
 15 transforming each overlapped-and-segmented input signal  $x'_p[n]$  by FFT to form a  
 16 segmented input frequency spectrum  $X'_p[k]$ ;  
 17 buffering said segmented input frequency spectrum to form buffered segmented input  
 18 frequency spectra  $X'_{p-s}[k]$  for  $s = 0, 1, 2, \dots, M$  and  $p = 0, 1, 2, \dots, \infty$ ;  
 19 multiplying said  $M$  sets of segmented perceptual response frequency spectra  $H'_s[k]$   
 20 with last buffered  $M$  segmented input frequency spectra  $X'_{p-s}[k]$  to form products  $X'_{p-s}[k] \cdot H'_s[k]$   
 21 for  $s = 0, 1, 2, \dots, M-1$  and adding said products together to form a  
 22 segmented output frequency spectrum

$$Y_p[k] = \sum_{s=0}^{M-1} X'_{p-s}[k] H'_s[k], \text{ for } 0 \leq k < 2N-1;$$

24 inverse transforming said segmented output frequency spectrum  $Y_p[k]$  to form  
 25 segmented output signals  $y_p[n]$ ; and  
 26 generating a final output signal  $y[n]$  by discarding first  $N$  samples of  $y_p[n]$ .

- 1 11. The method for efficient convolution according to claim 10, wherein said impulse  
2 response has a length  $L$  and  $M = \left\lceil \frac{L}{N} \right\rceil$  is a smallest integer larger than  $L$  divided by  
3  $N$ .
- 1 12. An apparatus for efficient convolution, comprising:  
2 a plurality of perceptual sparse processing units for removing high frequency  
3 components from a plurality of segmented response frequency spectra to form a  
4 plurality of segmented perceptual response frequency spectra; and  
5 a FIR-filter receiving said plurality of segmented perceptual response frequency  
6 spectra;  
7 wherein each of said perceptual sparse processing units removes high frequency  
8 components from a segmented response frequency spectrum based on a threshold.
- 1 13. The apparatus for efficient convolution as claimed in claim 12, wherein said FIR filter  
2 is implemented by a frequency domain convolution method based on an overlap-and-  
3 add method.
- 1 14. The apparatus for efficient convolution as claimed in claim 12, wherein said FIR-  
2 filter is implemented by a frequency domain convolution method based on an  
3 overlap-and-save method.
- 1 15. The apparatus for efficient convolution as claimed in claim 12, wherein said FIR-  
2 filter comprises a first section in which frequency domain convolution is computed  
3 with a first block size for reducing latency and a second section in which frequency  
4 domain convolution is computed with a second block size.

1 16. An apparatus for efficient convolution, comprising:  
2 a segmenting unit for segmenting an input signal into segmented input signals;  
3 a FFT processor for performing fast Fourier transform on each segmented input signal  
4 to a segmented input frequency spectrum;  
5 a plurality of perceptual sparse processing units for removing high frequency  
6 components from a plurality of segmented response frequency spectra to form a  
7 plurality of segmented perceptual response frequency spectra;  
8 a plurality of memory devices for storing said plurality of segmented perceptual  
9 response frequency spectra;  
10 a plurality of multipliers for multiplying said segmented input frequency spectrum  
11 with said plurality of segmented perceptual response frequency spectra to form a  
12 plurality of segmented output frequency spectra;  
13 a plurality of IFFT processors for performing inverse fast Fourier transform on said  
14 plurality of segmented output frequency spectra to form a plurality of segmented  
15 output signals; and  
16 a plurality of overlap-and-add units for overlapping and adding said plurality of  
17 segmented output signals to form a final output signal;  
18 wherein each of said perceptual sparse processing units removes high frequency  
19 components from a segmented response frequency spectrum based on a threshold.

1 17. An apparatus for efficient convolution, comprising:

2 a segmenting unit for segmenting an input signal into segmented input signals;

3 a FFT processor for performing fast Fourier transform on each segmented input signal  
4 to a segmented input frequency spectrum;  
5 a plurality of perceptual sparse processing units for removing high frequency  
6 components from a plurality of segmented response frequency spectra to form a  
7 plurality of segmented perceptual response frequency spectra;  
8 a plurality of memory devices for storing said plurality of segmented perceptual  
9 response frequency spectra;  
10 a plurality of buffers for buffering a plurality of segmented input frequency spectra;  
11 a plurality of multipliers for multiplying said buffered plurality of segmented input  
12 frequency spectra with said plurality of segmented perceptual response frequency  
13 spectra to form a plurality of segmented output frequency spectra;  
14 a summation unit for adding said plurality of segmented output frequency spectra to  
15 form an output frequency spectrum;  
16 an IFFT processor for performing inverse fast Fourier transform on said output  
17 frequency spectrum to form an output signal; and  
18 an overlap-and-add unit for overlapping and adding said output signal to form a final  
19 output signal;  
20 wherein each of said perceptual sparse processing units removes high frequency  
21 components from a segmented response frequency spectrum based on a threshold .

1 18. An apparatus for efficient convolution, comprising:

2 an overlapping and segmenting unit for overlapping and segmenting an input signal



3 into overlapped-and-segmented input signals;  
4 a FFT processor for performing fast Fourier transform on each overlapped-and-  
5 segmented input signal to a segmented input frequency spectrum;  
6 a plurality of perceptual sparse processing units for removing high frequency  
7 components from a plurality of segmented response frequency spectra to form a  
8 plurality of segmented perceptual response frequency spectra;  
9 a plurality of memory devices for storing said plurality of segmented perceptual  
10 response frequency spectra;  
11 a plurality of buffers for buffering a plurality of segmented input frequency spectra;  
12 a plurality of multipliers for multiplying said buffered plurality of segmented input  
13 frequency spectra with said plurality of segmented perceptual response frequency  
14 spectra to form a plurality of segmented output frequency spectra;  
15 a summation unit for adding said plurality of segmented output frequency spectra to  
16 form an output frequency spectrum;  
17 an IFFT processor for performing inverse fast Fourier transform on said output  
18 frequency spectrum to form an output signal; and  
19 a discarding unit for discarding a number of samples from said output signal to form a  
20 final output signal;  
21 wherein each of said perceptual sparse processing units removes high frequency  
22 components from a segmented response frequency spectrum based on a threshold.

1 19. A method for efficient convolution, comprising the steps of:

2 preparing a plurality of segmented response frequency spectra;  
3 generating a plurality of segmented input frequency spectra from a plurality of  
4 segmented input signals;  
5 removing high frequency components from said plurality of segmented input  
6 frequency spectra to form a plurality of segmented perceptual input frequency spectra;  
7 and  
8 performing a frequency domain convolution method to generate convoluted signals  
9 using said plurality of segmented response frequency spectra and said plurality of  
10 segmented perceptual input frequency spectra;  
11 wherein said plurality of segmented perceptual input frequency spectra are generated  
12 by removing high frequency components from said plurality of segmented input  
13 frequency spectra based a threshold.

1 20. The method for efficient convolution as claimed in claim 19, wherein said efficient  
2 convolution is used for generating artificial room reverberation and said threshold is  
3 based on a threshold in quiet, said threshold being determined by the minimum  
4 amount of energy in a pure tone detected by a human hearing system in a noiseless  
5 environment.

1 21. The method for efficient convolution as claimed in claim 19, wherein said frequency  
2 domain convolution method is an overlap-and-add method by using FFT.

1 22. The method for generating efficient convolution as claimed in claim 1, wherein said  
2 frequency domain convolution method is an overlap-and-save method by using FFT.

1 23. The method for efficient convolution as claimed in claim 19, wherein said segmented

2 input signals have a segment size for segmentation and in the step of performing a  
 3 frequency domain convolution method to generate convoluted signals, first and  
 4 second segments of convoluted signals are generated by convolution using a block  
 5 size smaller than the segment size.

1 24. A method for efficient convolution, comprising the steps of:

2 preparing an impulse response  $h[n]$ ;

3 segmenting said impulse response into  $M$  segmented impulse responses  $h_s[n]$ ,

4 wherein  $h_s[n] = \begin{cases} h[n + sN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, s = 0, 1, 2, \dots, M-1;$

5 transforming said  $M$  segmented impulse responses  $h_s[n]$  by DFT to form  $M$

6 segmented response frequency spectra  $H_s[k]$  with  $0 \leq k < 2N$ ;

7 receiving and segmenting an input signal  $x[n]$  into a plurality of segmented input

8 signals  $x_r[n]$ , wherein  $x_r[n] = \begin{cases} x[n + rN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, r = 0, 1, 2, \dots, \infty;$

9 transforming each segmented input signal  $x_r[n]$  by DFT to form a segmented input

10 frequency spectrum  $X_r[k]$ ;

11 removing high frequency components from said segmented input frequency spectra

12  $X_r[k]$  based on a threshold to a segmented perceptual input frequency spectra  $X'_r[k]$ ;

13 multiplying said segmented perceptual input frequency spectrum  $X'_r[k]$  with said  $M$

14 sets of segmented response frequency spectra  $H_s[k]$  for  $s = 0, 1, 2, \dots, M-1$  to form  $M$

15 segmented output frequency spectra  $Y_{r,s}[k] = X'_r[k] \cdot H_s[k]$ ;

16 inverse transforming said  $M$  output frequency spectra  $Y_{r,s}[k]$  to form  $M$  segmented

17 output signals  $y_{r,s}[n]$ ; and

18 performing overlap-and-add summation of said  $M$  segmented output signals  $y_{r,s}[n]$  to

form a final output signal  $y[n]$  according to

$$y[n] = \sum_{r=0}^{\infty} \sum_{s=0}^{M-1} y_{r,s}[n - rN - sN].$$

25. The method for efficient convolution according to claim 24, wherein said impulse response has a length  $L$  and  $M = \left\lceil \frac{L}{N} \right\rceil$  is a smallest integer larger than  $L$  divided by  $N$ .

26. A method for efficient convolution, comprising the steps of:

preparing an impulse response  $h[n]$ ;

segmenting said impulse response into  $M$  segmented impulse responses  $h_s[n]$ ,

wherein  $h_s[n] = \begin{cases} h[n + sN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, s = 0, 1, 2, \dots, M-1;$

transforming said  $M$  segmented impulse responses  $h_s[n]$  by DFT to form  $M$  segmented response frequency spectra  $H_s[k]$  with  $0 \leq k < 2N$ ;

receiving and segmenting an input signal  $x[n]$  into a plurality of segmented input

signals  $x_r[n]$ , wherein  $x_r[n] = \begin{cases} x[n + rN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, r = 0, 1, 2, \dots, \infty;$

transforming each segmented input signal  $x_r[n]$  by FFT to form a segmented input frequency spectrum  $X_r[k]$ ;

removing high frequency components from said segmented input frequency spectrum  $X_r[k]$  based on a threshold to form a segmented perceptual input frequency spectrum  $X'_r[k]$ ;

buffering said segmented perceptual input frequency spectrum to form buffered segmented perceptual input frequency spectra  $X'_{p-s}[k]$  for  $s = 0, 1, 2, \dots, M$  and  $p = 0,$

16 1, 2, ...,  $\infty$ ;  
 17 multiplying said  $M$  sets of segmented response frequency spectra  $H_s[k]$  with last  
 18 buffered  $M$  segmented perceptual input frequency spectra  $X'_{p-s}[k]$  to form products  
 19  $X'_{p-s}[k] \cdot H_s[k]$  for  $s = 0, 1, 2, \dots, M-1$  and adding said products together to form a  
 20 segmented output frequency spectrum

$$21 \quad Y_p[k] = \sum_{s=0}^{M-1} X'_{p-s}[k] H_s[k], \text{ for } 0 \leq k < 2N-1;$$

22 inverse transforming said segmented output frequency spectrum  $Y_p[k]$  to form  
 23 segmented output signals  $y_p[n]$ ; and  
 24 performing overlap-and-add summation of said  $M$  segmented output signals  $y_p[n]$  to  
 25 form a final output signal  $y[n]$  according to

$$26 \quad y[n] = \sum_{p=s}^{\infty} y_p[n].$$

1 27. The method for efficient convolution according to claim 26, wherein said impulse  
 2 response has a length  $L$  and  $M = \left\lceil \frac{L}{N} \right\rceil$  is a smallest integer larger than  $L$  divided by  
 3  $N$ .

1 28. A method for efficient convolution, comprising the steps of:

2 preparing an impulse response  $h[n]$  of ;

3 segmenting said impulse response into  $M$  segmented impulse responses  $h_s[n]$ ,

$$4 \quad \text{wherein } h_s[n] = \begin{cases} h[n + sN], & 0 \leq n \leq N-1 \\ 0, & \text{otherwise} \end{cases}, s = 0, 1, 2, \dots, M-1;$$

5 transforming said segmented impulse responses  $h_s[n]$  by DFT to form  $M$  segmented  
 6 response frequency spectra  $H_s[k]$  with  $0 \leq k < 2N$ ;

7 receiving and segmenting an input signal  $x[n]$  into a plurality of segmented input

8 signals  $x_r[n]$ , wherein  $x_r[n] = \begin{cases} x[n + rN], & 0 \leq n \leq N - 1 \\ 0, & \text{otherwise} \end{cases}, r = 0, 1, 2, \dots, \infty;$

9 overlapping and adding adjacent segmented input signals to form a plurality of

10 overlapped-and-segmented input signals  $x'_p[n] = x_{p-1}[n + N] + x_p[n], -N \leq n \leq$   
11  $N - 1;$

12 transforming each overlapped-and-segmented input signal  $x'_p[n]$  by FFT to form a  
13 segmented input frequency spectrum  $X'_p[k];$

14 removing high frequency components from said segmented input frequency spectrum  
15  $X'_p[k]$  based on a threshold to form a segmented perceptual input frequency spectrum  
16  $X''_p[k];$

17 buffering said segmented perceptual input frequency spectrum to form buffered  
18 segmented perceptual input frequency spectra  $X''_{p-s}[k]$  for  $s = 0, 1, 2, \dots, M$  and  $p = 0,$   
19  $1, 2, \dots, \infty;$

20 multiplying said  $M$  sets of segmented response frequency spectra  $H_s[k]$  with last  
21 buffered  $M$  segmented perceptual input frequency spectra  $X''_{p-s}[k]$  to form products  
22  $X''_{p-s}[k] \cdot H_s[k]$  for  $s = 0, 1, 2, \dots, M-1$  and adding said products together to form a  
23 segmented output frequency spectrum

24 
$$Y_p[k] = \sum_{s=0}^{M-1} X''_{p-s}[k] H_s[k], \text{ for } 0 \leq k < 2N-1;$$

25 inverse transforming said segmented output frequency spectrum  $Y_p[k]$  to form  
26 segmented output signals  $y_p[n];$  and

27 generating a final output signal  $y[n]$  by discarding first  $N$  samples of  $y_p[n].$

1 29. The method for efficient convolution according to claim 28, wherein said impulse  
2 response has a length  $L$  and  $M = \left\lceil \frac{L}{N} \right\rceil$  is a smallest integer larger than  $L$  divided by  
3  $N$ .

1 30. An apparatus for efficient convolution, comprising:

2 a segmenting unit for segmenting an input signal into segmented input signals;

3 a FFT processor for performing fast Fourier transform on each segmented input signal  
4 to a segmented input frequency spectrum;

5 a perceptual sparse processing unit for removing high frequency components from  
6 said segmented input frequency spectrum to form a segmented perceptual input  
7 frequency spectrum;

8 a plurality of memory devices for storing a plurality of segmented response frequency  
9 spectra;

10 a plurality of multipliers for multiplying said segmented perceptual input frequency  
11 spectrum with said plurality of segmented response frequency spectra to form a  
12 plurality of segmented output frequency spectra;

13 a plurality of IFFT processors for performing inverse fast Fourier transform on said  
14 plurality of segmented output frequency spectra to form a plurality of segmented  
15 output signals; and

16 a plurality of overlap-and-add units for overlapping and adding said plurality of  
17 segmented output signals to form a final output signal;

18 wherein said perceptual sparse processing unit removes high frequency components

19 from said segmented input frequency spectrum based on a threshold.

1 31. An apparatus for efficient convolution, comprising:

2 a segmenting unit for segmenting an input signal into segmented input signals;

3 a FFT processor for performing fast Fourier transform on each segmented input signal

4 to a segmented input frequency spectrum;

5 a perceptual sparse processing unit for removing high frequency components from

6 said segmented input frequency spectrum to form a segmented perceptual input

7 frequency spectrum;

8 a plurality of memory devices for storing a plurality of segmented response frequency

9 spectra;

10 a plurality of buffers for buffering a plurality of said segmented perceptual input

11 frequency spectra;

12 a plurality of multipliers for multiplying said buffered plurality of segmented

13 perceptual input frequency spectra with said plurality of segmented response

14 frequency spectra to form a plurality of segmented output frequency spectra;

15 a summation unit for adding said plurality of segmented output frequency spectra to

16 form an output frequency spectrum;

17 an IFFT processor for performing inverse fast Fourier transform on said output

18 frequency spectrum to form an output signal; and

19 an overlap-and-add unit for overlapping and adding said output signal to form a final

20 output signal;



21 wherein said perceptual sparse processing unit removes high frequency components  
22 from said segmented input frequency spectrum based on a threshold.

1 32. An apparatus for efficient convolution, comprising:

2 an overlapping and segmenting unit for overlapping and segmenting an input signal  
3 into overlapped-and-segmented input signals;

4 a FFT processor for performing fast Fourier transform on each overlapped-and-  
5 segmented input signal to a segmented input frequency spectrum;

6 a perceptual sparse processing unit for removing high frequency components from  
7 said segmented input frequency spectrum to form a segmented perceptual input  
8 frequency spectrum;

9 a plurality of memory devices for storing a plurality of segmented response frequency  
10 spectra;

11 a plurality of buffers for buffering a plurality of said segmented perceptual input  
12 frequency spectra;

13 a plurality of multipliers for multiplying said buffered plurality of segmented  
14 perceptual input frequency spectra with said plurality of segmented response  
15 frequency spectra to form a plurality of segmented output frequency spectra;

16 a summation unit for adding said plurality of segmented output frequency spectra to  
17 form an output frequency spectrum;

18 an IFFT processor for performing inverse fast Fourier transform on said output  
19 frequency spectrum to form an output signal; and

20 a discarding unit for discarding a number of samples from said output signal to form a  
21 final output signal;  
22 wherein said perceptual sparse processing unit removes high frequency components  
23 from said segmented input frequency spectrum based on a threshold.

1